Microphysics in convection parameterization: comparison with TWP-ICE data

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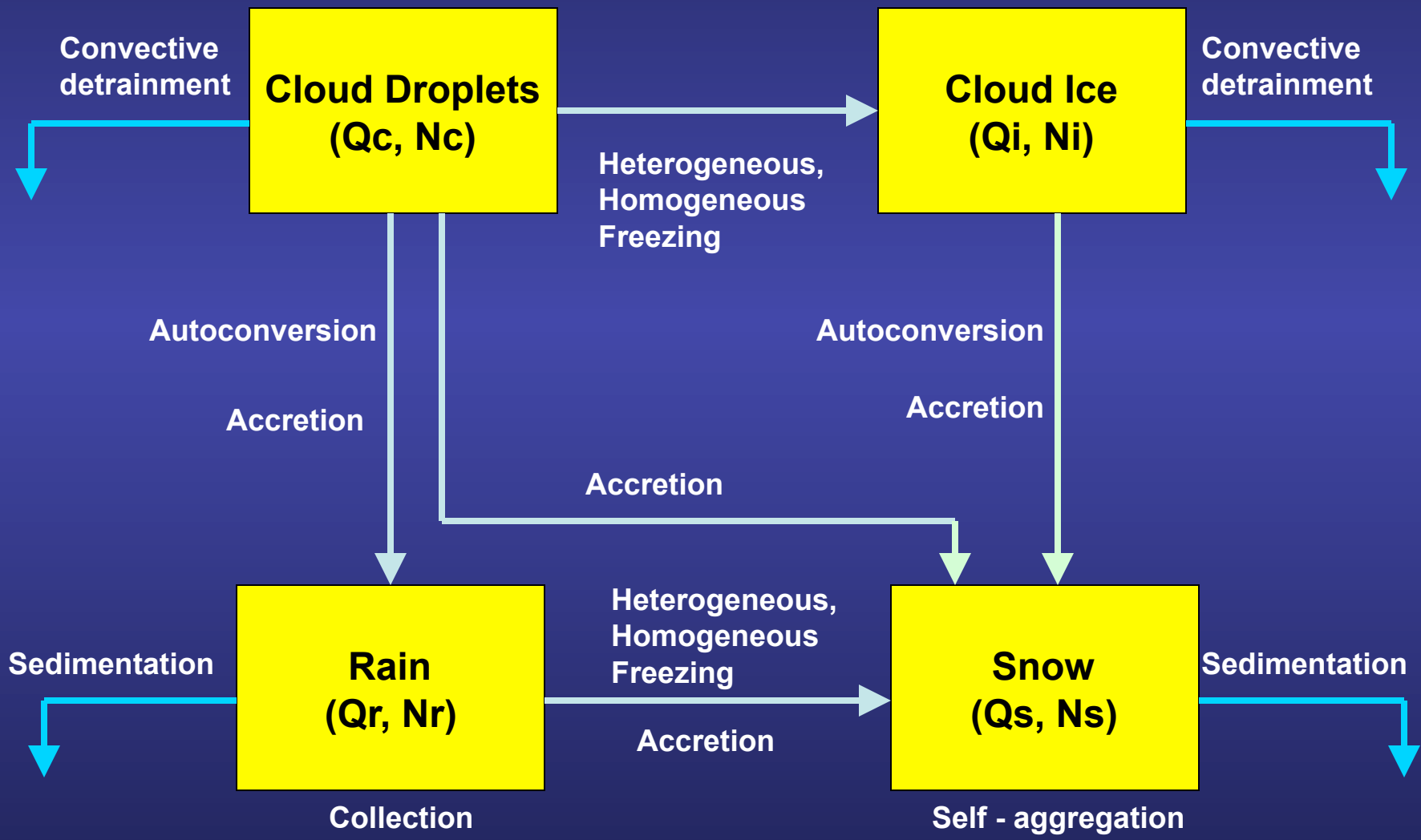
Motivation

- To describe microphysical processes more realistically in convection parameterization.
- To allow for better treatment of convective cloud-aerosol interactions
- To be consistent with microphysics schemes for stratiform clouds in the new generation CAM.

Two-moment microphysics scheme for convective clouds



Equations

$$\frac{\partial}{\partial z}(M_u q_l) = -D_u q_l + \frac{M_u}{w_u}(P_{cond}^{q_l} - P_{auto}^{q_l} - P_{accr}^{q_l} - P_{accs}^{q_l} - P_{f\,het}^{q_l} - P_{f\,hm}^{q_l})$$

$$\frac{\partial}{\partial z}(M_u N_l) = -D_u N_l + \frac{M_u}{w_u}(-P_{auto}^{N_l} - P_{accr}^{N_l} - P_{accs}^{N_l} - P_{f\,het}^{N_l} - P_{f\,hm}^{N_l})$$

$$\frac{\partial}{\partial z}(M_u q_i) = -D_u q_i + \frac{M_u}{w_u}(P_{cond}^{q_i} - P_{auto}^{q_i} - P_{accs}^{q_i} + P_{f\,het}^{q_l} + P_{f\,hm}^{q_l})$$

$$\frac{\partial}{\partial z}(M_u N_i) = -D_u N_i + \frac{M_u}{w_u}(P_{nuc}^{N_i} - P_{auto}^{N_i} - P_{accs}^{N_i} + P_{f\,het}^{N_l} + P_{f\,hm}^{N_l})$$

$$\frac{\partial}{\partial z}(M_u q_r) = \frac{M_u}{w_u}(P_{auto}^{q_l} + P_{accr}^{q_l} - P_{accs}^{q_r} - P_{f\,het}^{q_r} - P_{f\,hm}^{q_r} - P_{f\,allout}^{q_r})$$

$$\frac{\partial}{\partial z}(M_u N_r) = \frac{M_u}{w_u}(P_{auto}^{N_l} + P_{accr}^{N_l} - P_{accs}^{N_r} - P_{f\,het}^{N_r} - P_{f\,hm}^{N_r} - P_{f\,allout}^{N_r} + P_{aggr}^{N_r})$$

$$\frac{\partial}{\partial z}(M_u q_s) = \frac{M_u}{w_u}(P_{auto}^{q_i} + P_{accs}^{q_i} + P_{accs}^{q_r} + P_{accs}^{q_l} + P_{f\,het}^{q_r} + P_{f\,hm}^{q_r} - P_{f\,allout}^{q_s})$$

$$\frac{\partial}{\partial z}(M_u N_s) = \frac{M_u}{w_u}(P_{auto}^{N_i} + P_{accs}^{N_i} + P_{accs}^{N_r} + P_{accs}^{N_l} + P_{f\,het}^{N_r} + P_{f\,hm}^{N_r} - P_{f\,allout}^{N_s} + P_{aggs}^{N_s})$$

Preliminary results using SCAM

- Single-column version of CAM3.1.P2

  ZM : standard SCAM

  ZM_mphy : SCAM with new microphysics scheme

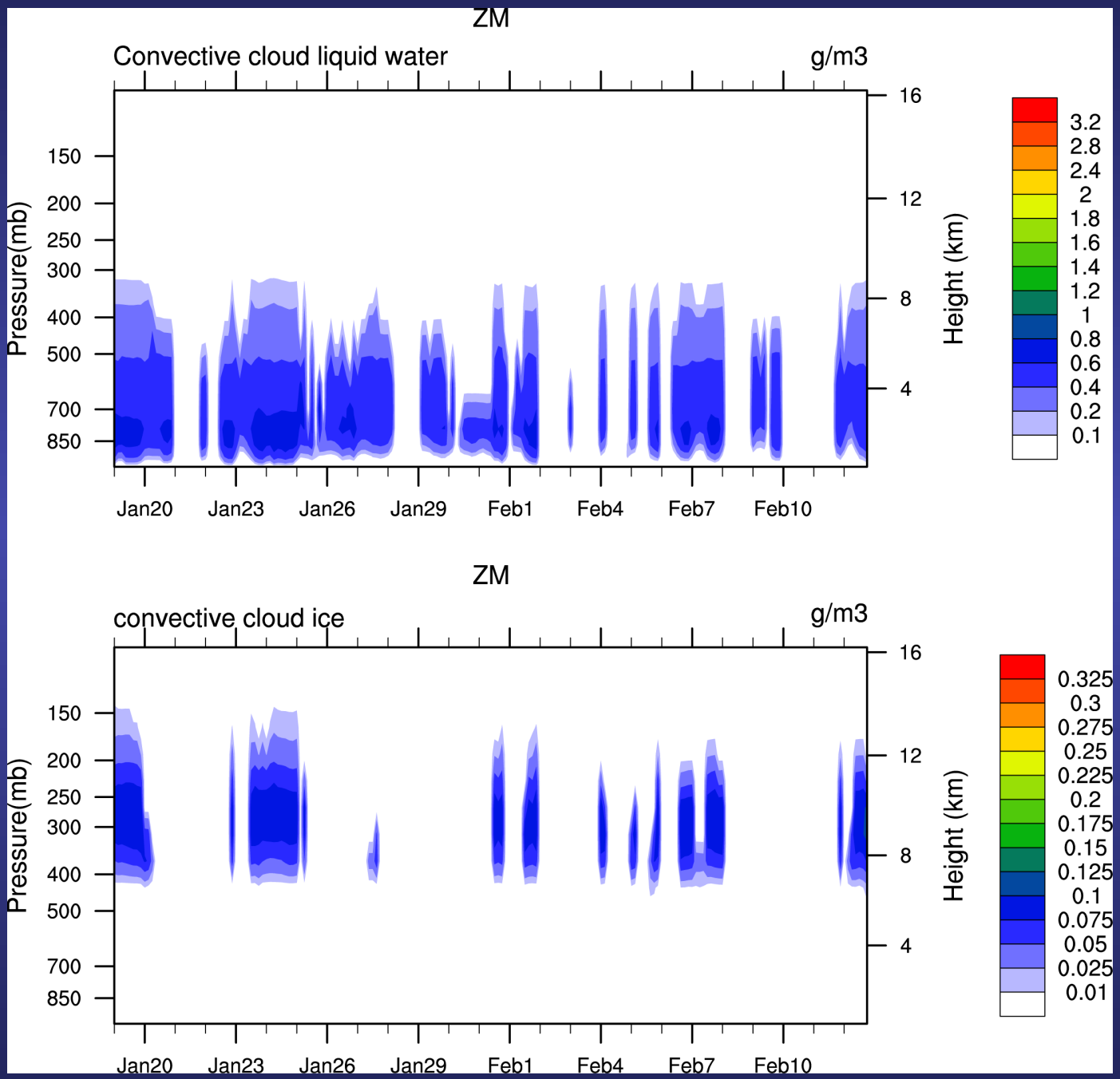
- TWP-ICE IOP: Jan 19 - Feb12, 2006.
- Validation data:

  Convective and total precipitation derived from CPOL radar

  Convective cloud ice and liquid water content derived from CPOL

  Convective cloud ice derived from satellite (*Seo and Liu*, 2005) and CPOL

  Radiative fluxes from VISST and ARM site, Cloud fraction from ARSCL


ZM
Convective cloud liquid water
g/m3
Pressure(mb)
150
200
250
300
400
500
700
850
Jan20
Jan23
Jan26
Jan29
Feb1
Feb4
Feb7
Feb10
16
12
8
4
Height (km)
3.2
2.8
2.4
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0.1
ZM
convective cloud ice
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Pressure(mb)
150
200
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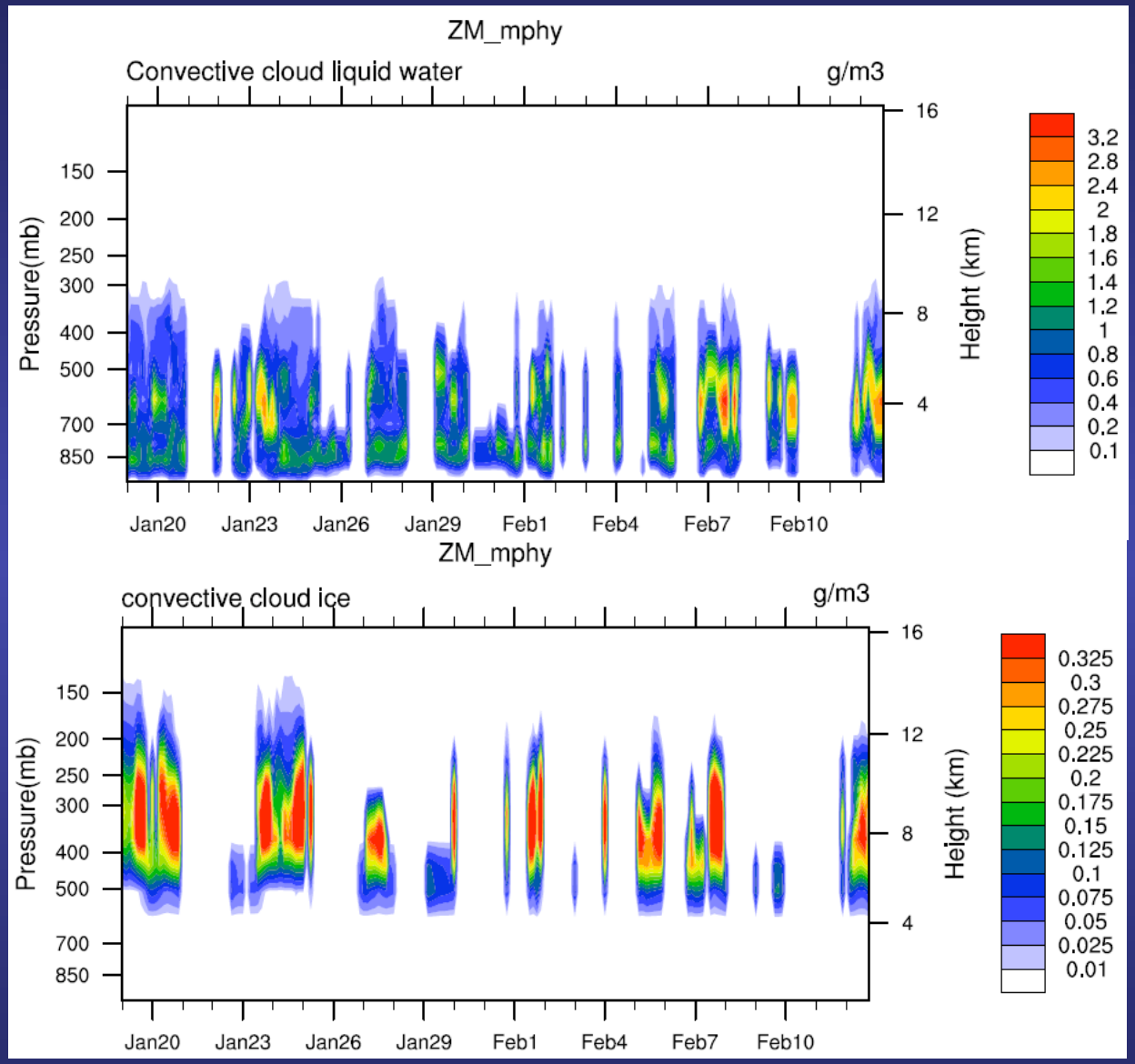
Height (km)
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0.01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0.025
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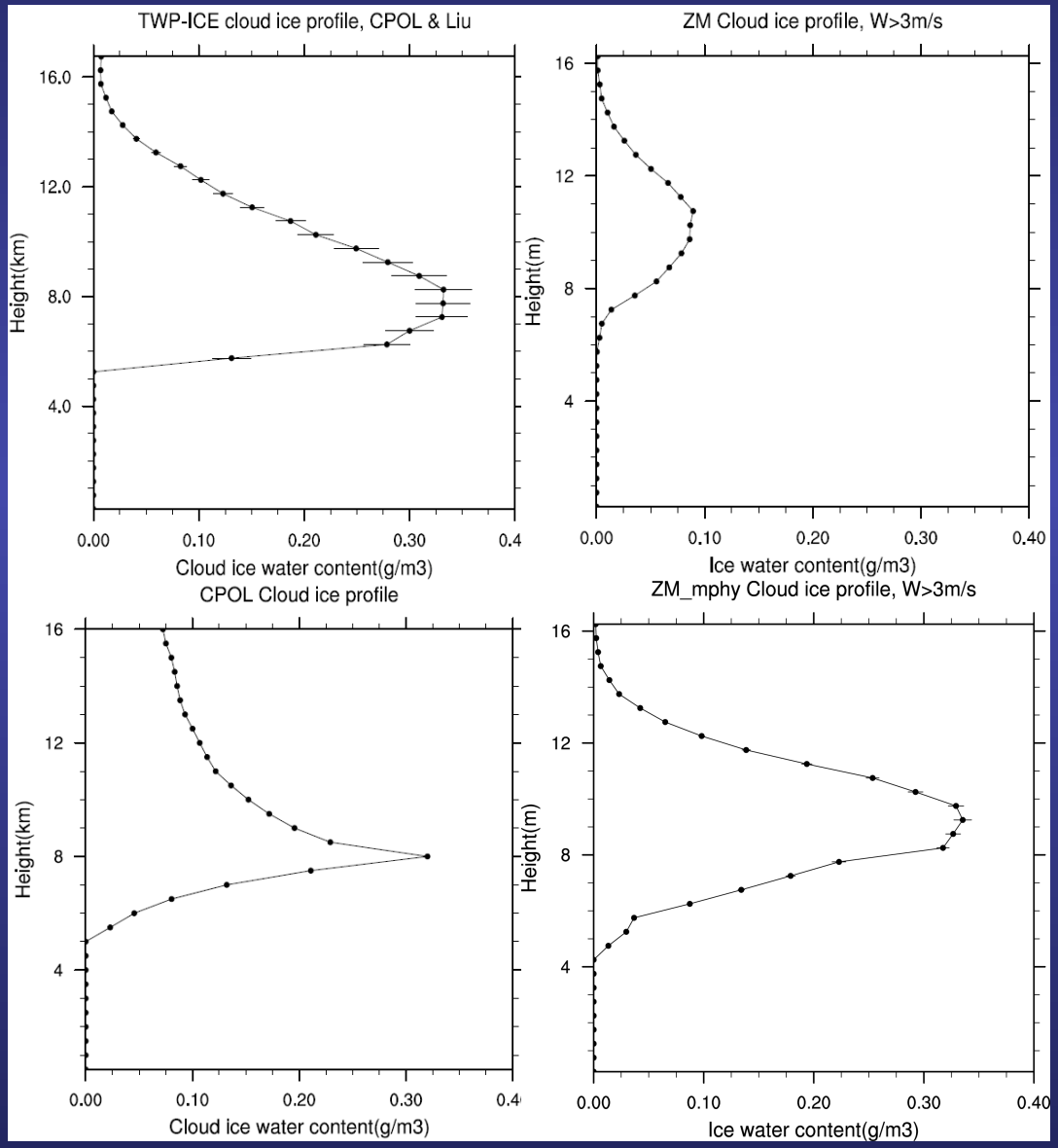
Convective cloud properties during active monsoon period
cloud ice

Satellite

ZM

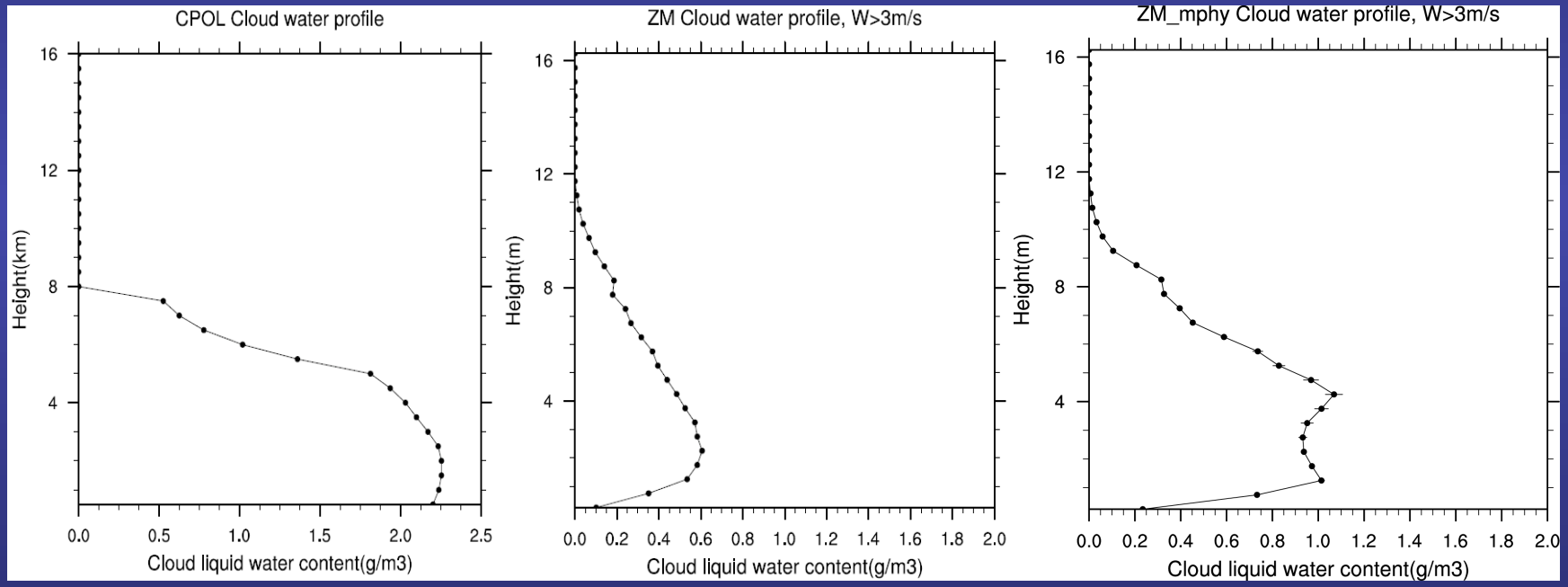
Radar

ZM_mphy



Convective cloud properties during active monsoon period
cloud liquid water

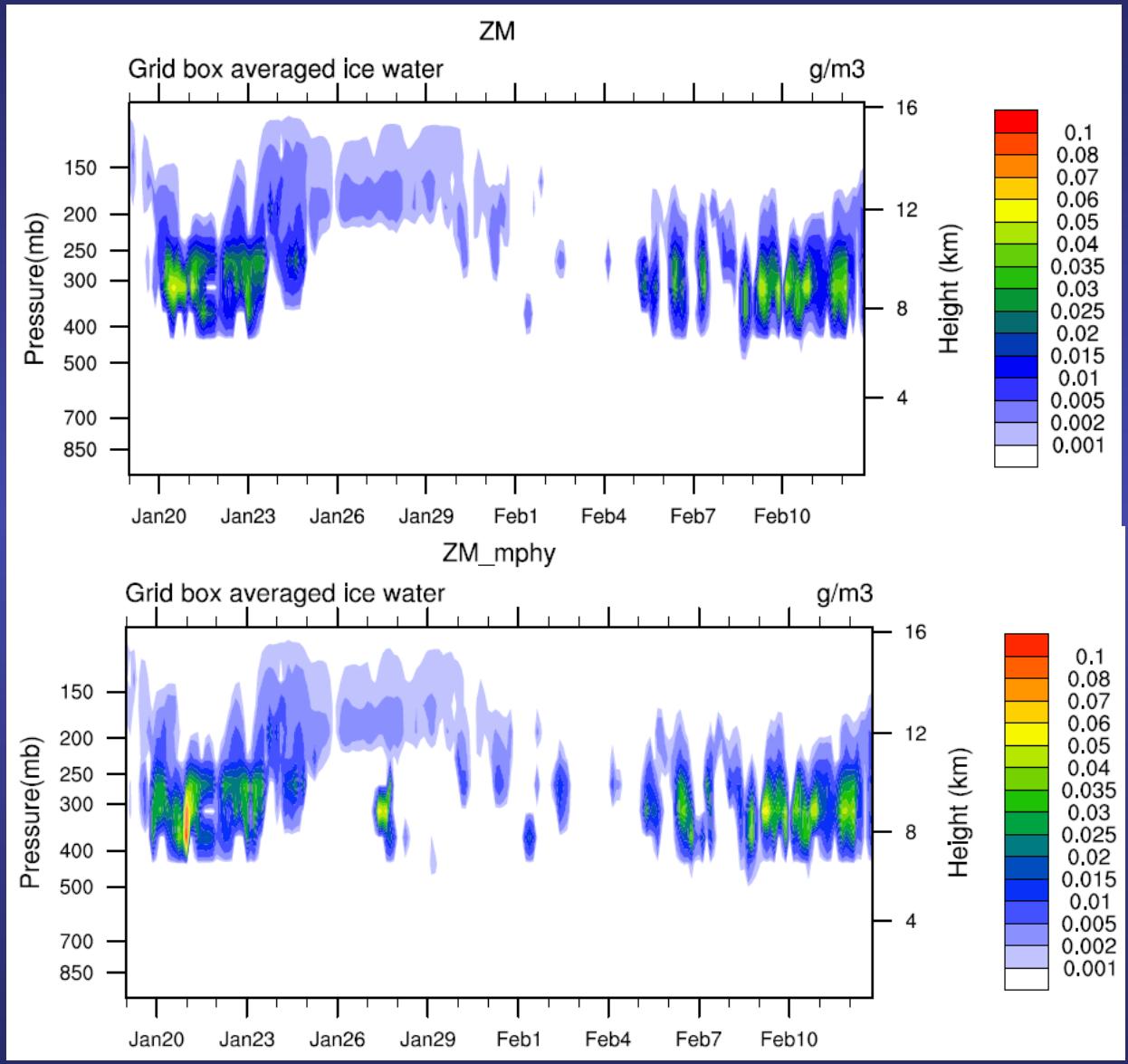
Radar ZM ZM_mphy



Impacts on simulation - cloud ice

ZM

ZM_mphy



Impacts on simulation - cloud liquid water

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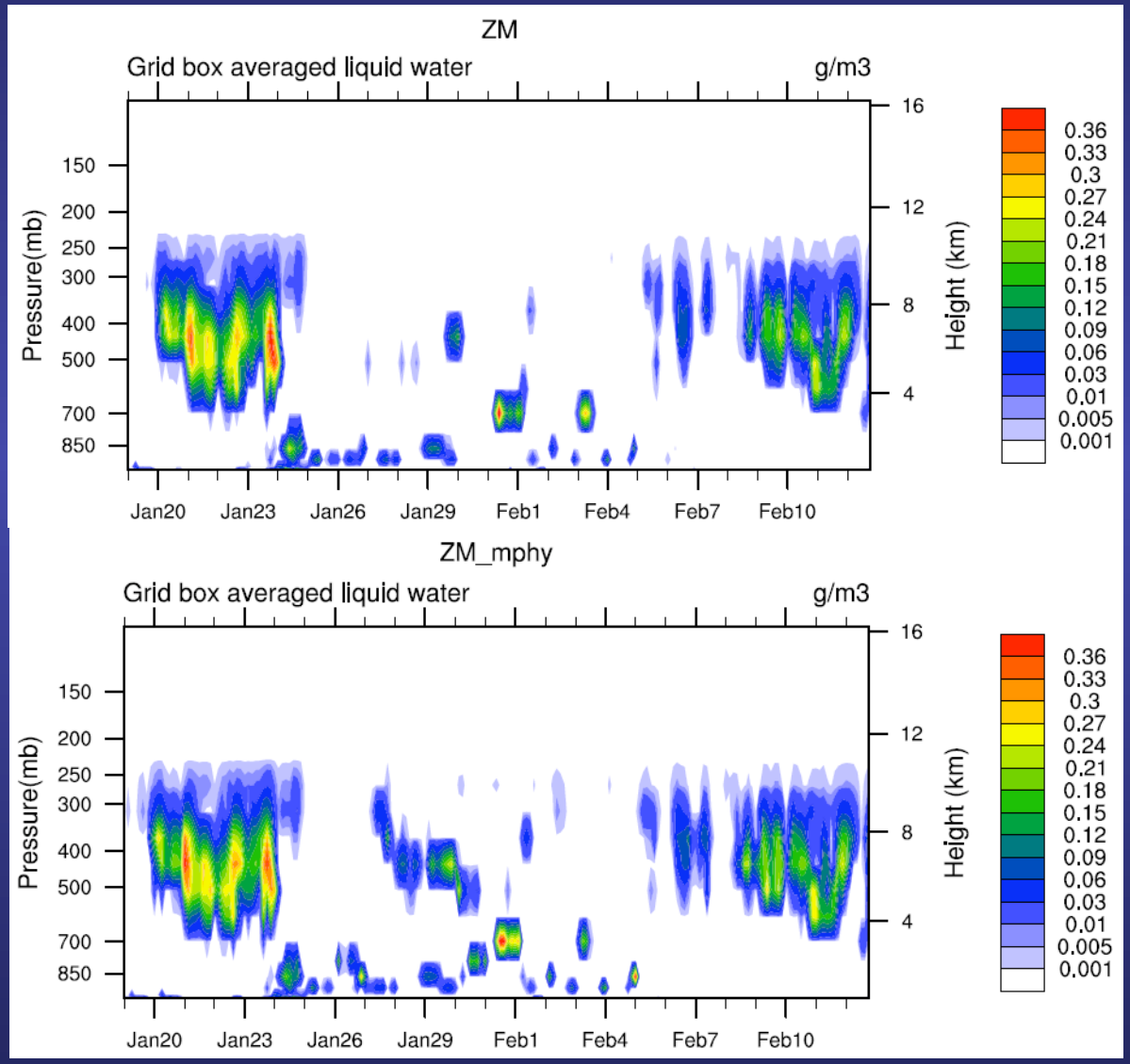
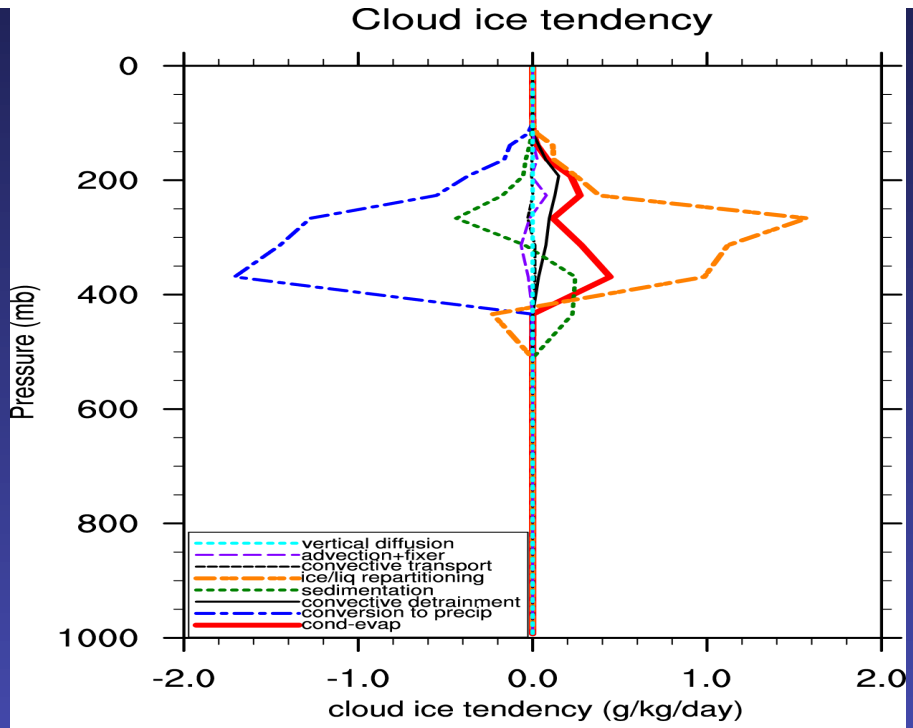
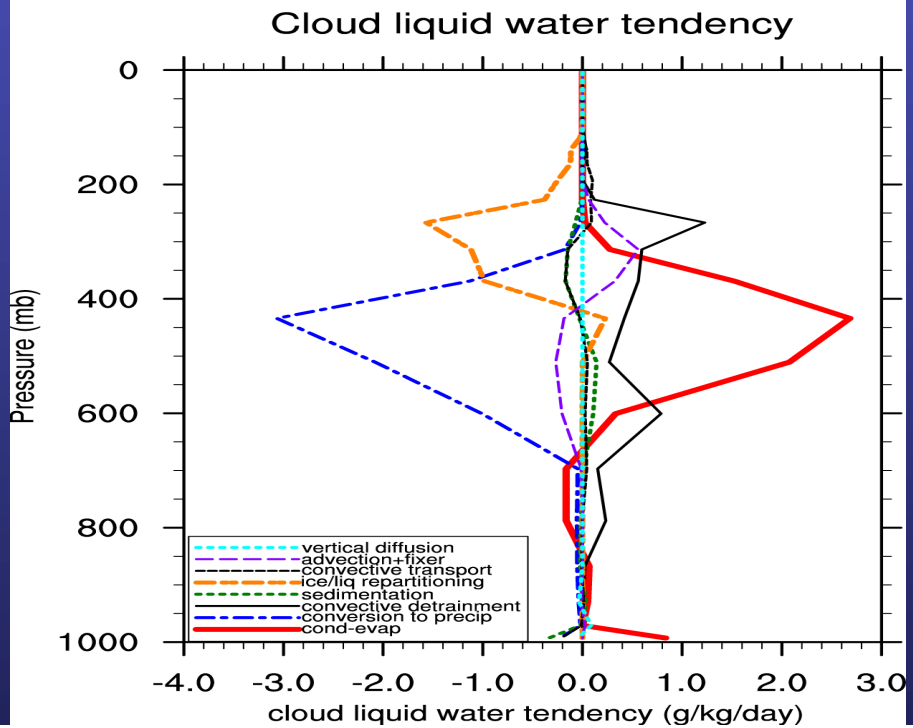
ZM_mphy




Cloud ice tendency
Pressure (mb)
0
200
400
600
800
1000
-2.0
-1.0
0.0
1.0
2.0
cloud ice tendency (g/kg/day)
vertical diffusion
advection+fixer
convective transport
ice/liq repartitioning
sedimentation
convective detrainment
conversion to precip
cond-evap


Cloud liquid water tendency
Pressure (mb)
0
200
400
600
800
1000
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
cloud liquid water tendency (g/kg/day)
vertical diffusion
advection+fixer
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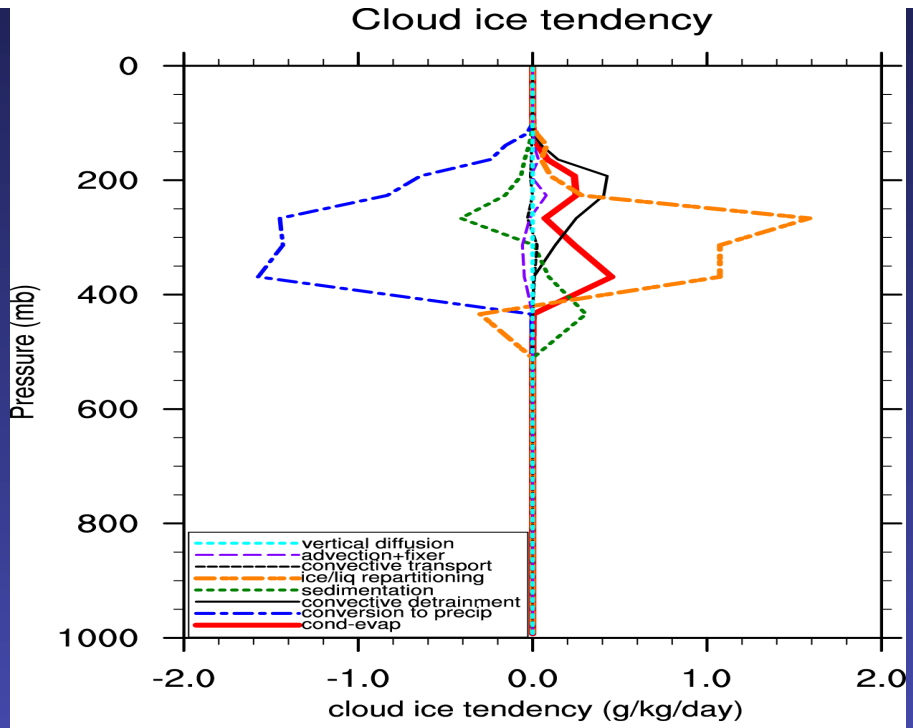
Cloud ice tendency
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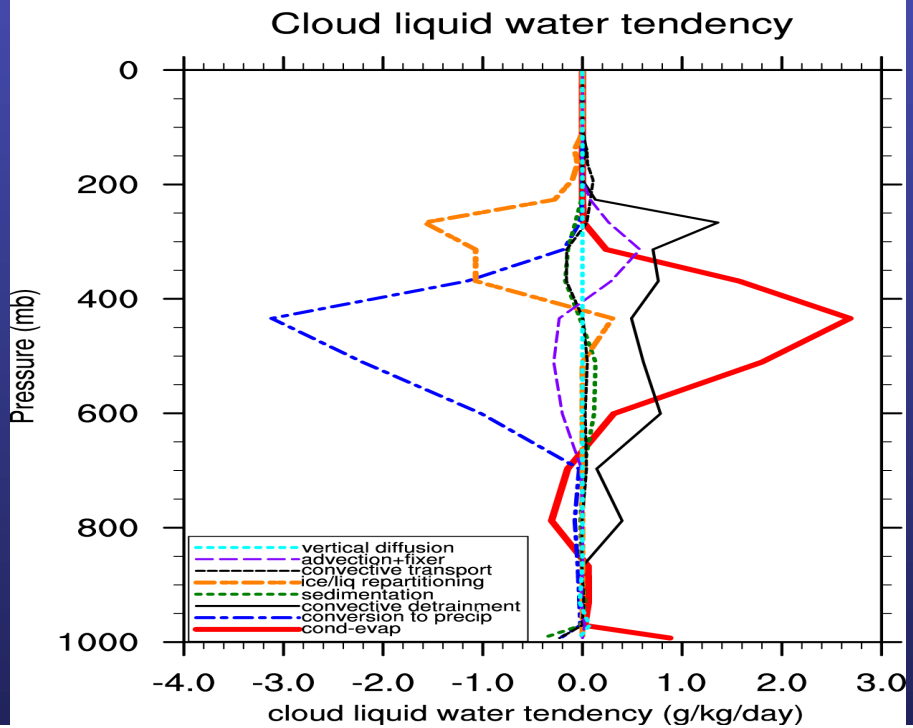
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cloud liquid water tendency (g/kg/day)
vertical diffusion
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conversion to precip
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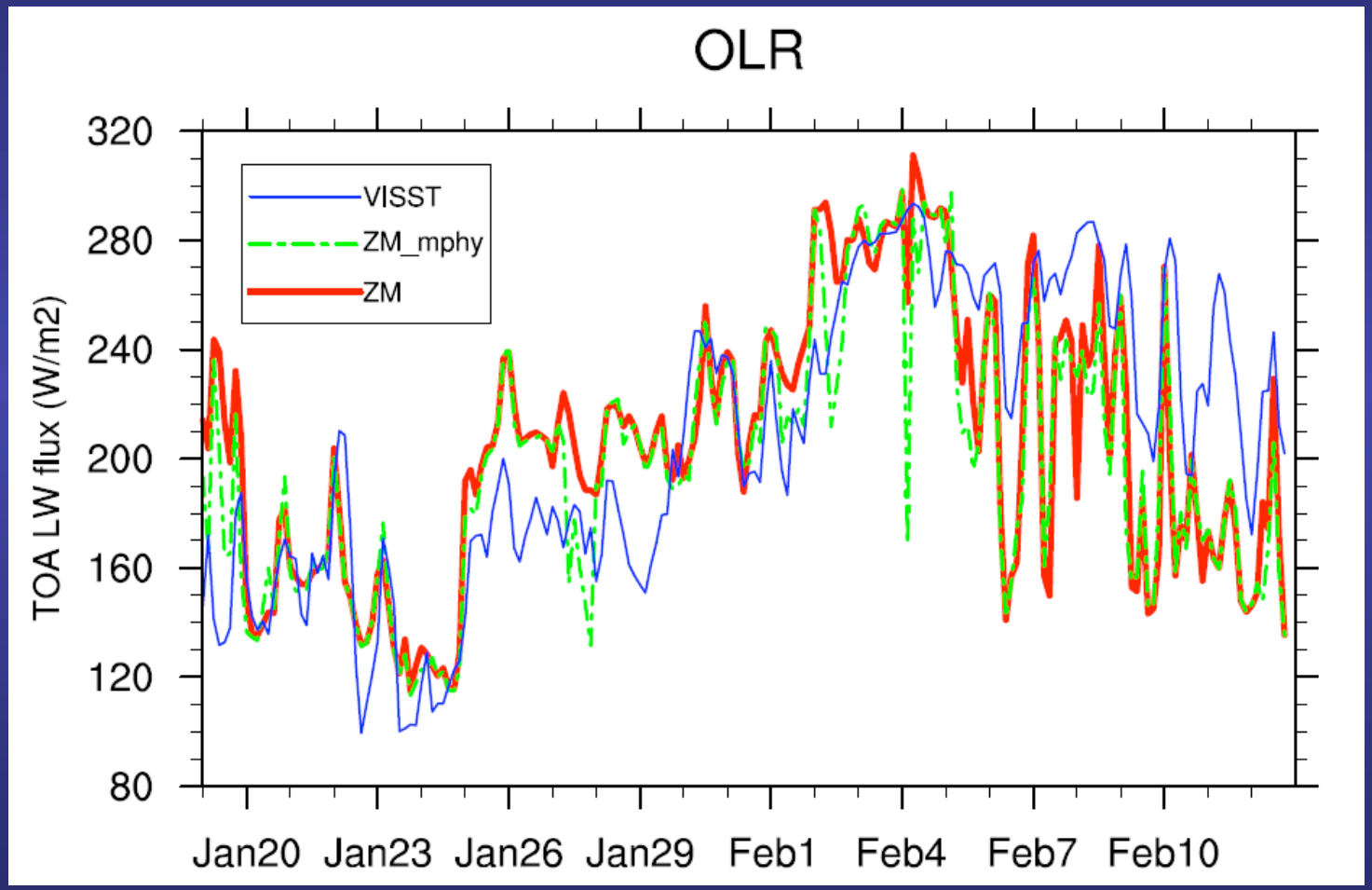
Impacts on simulation - OLR

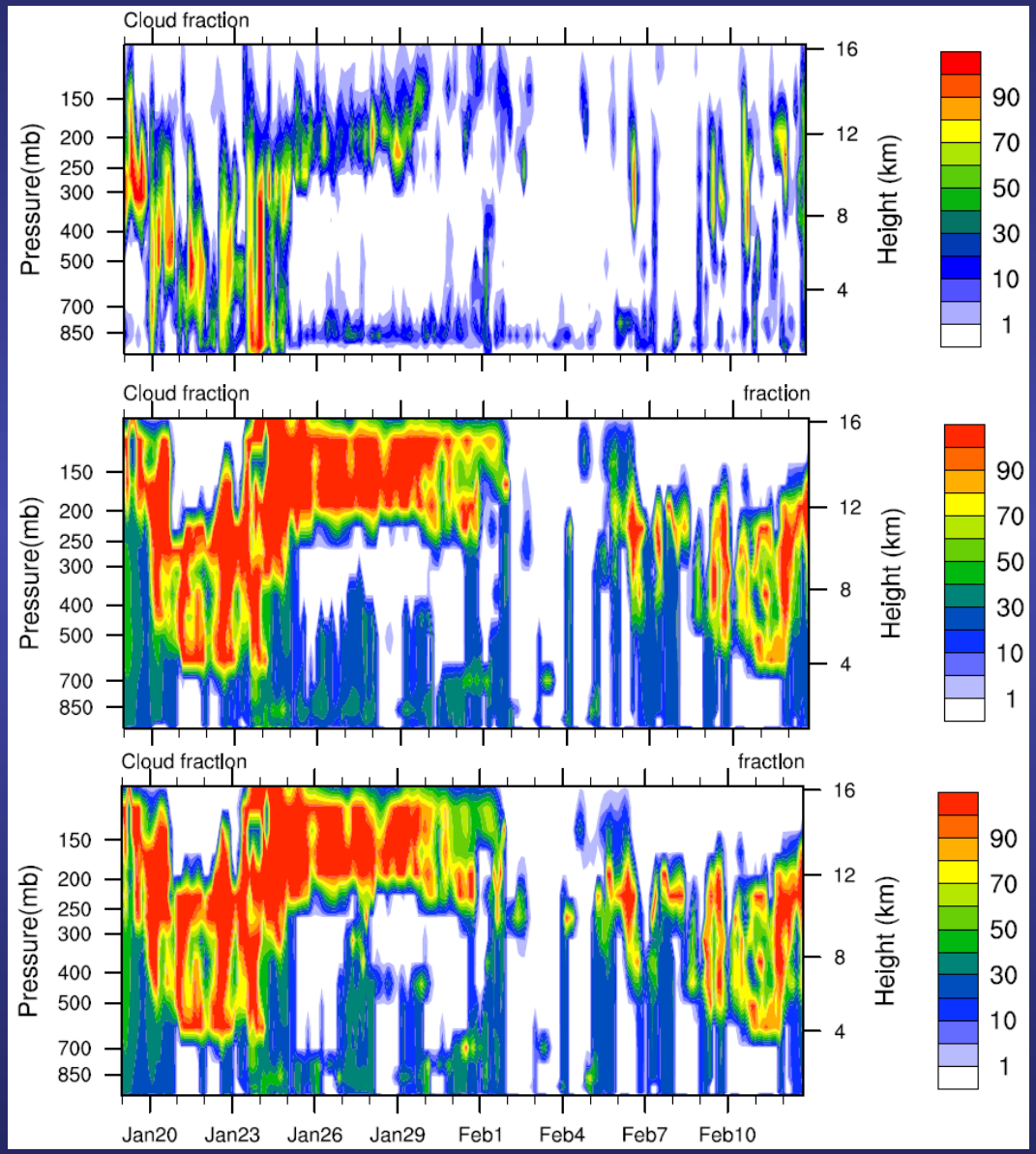


Impacts on simulation – Cloud fraction

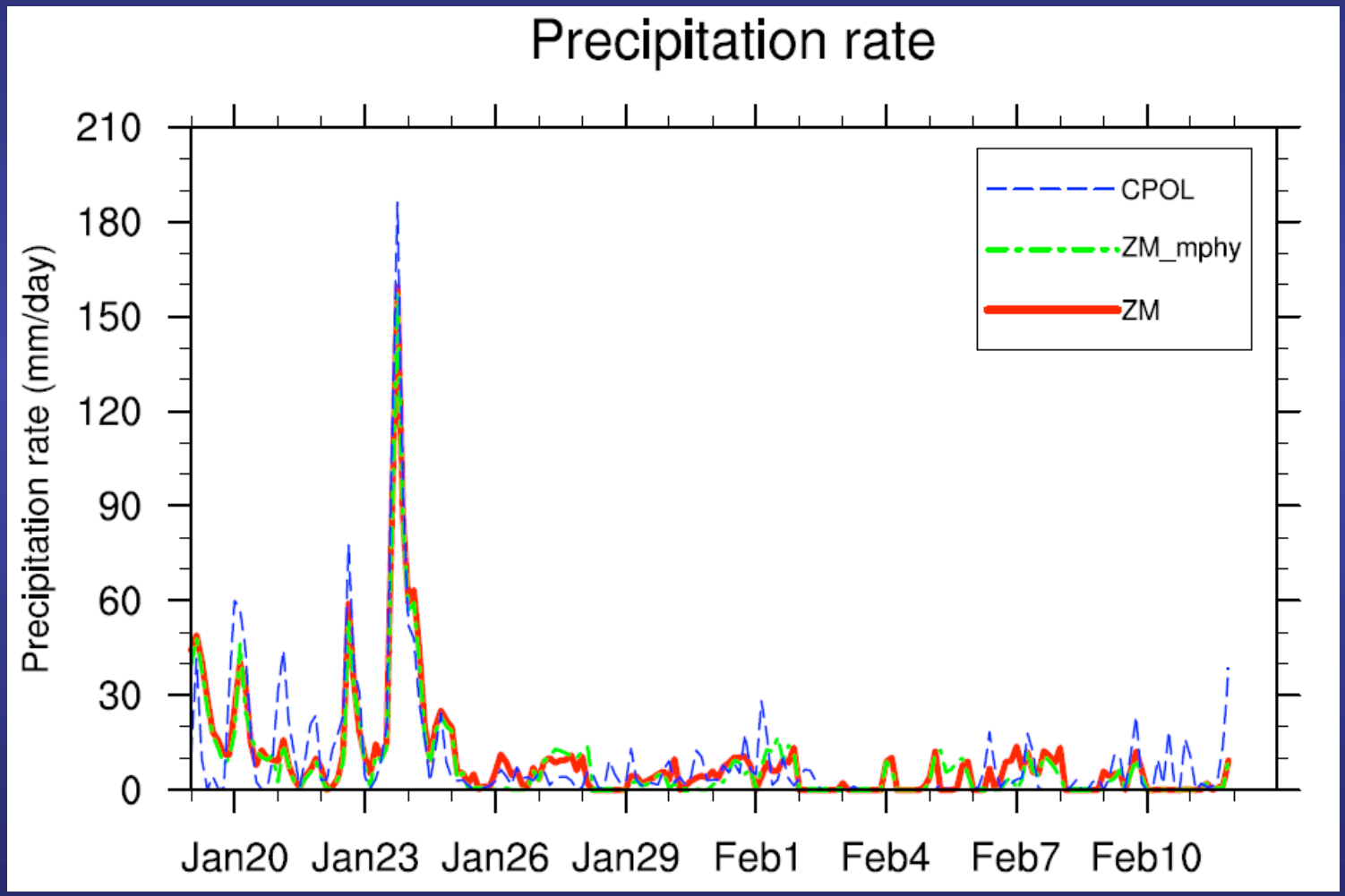
ARSCL

ZM

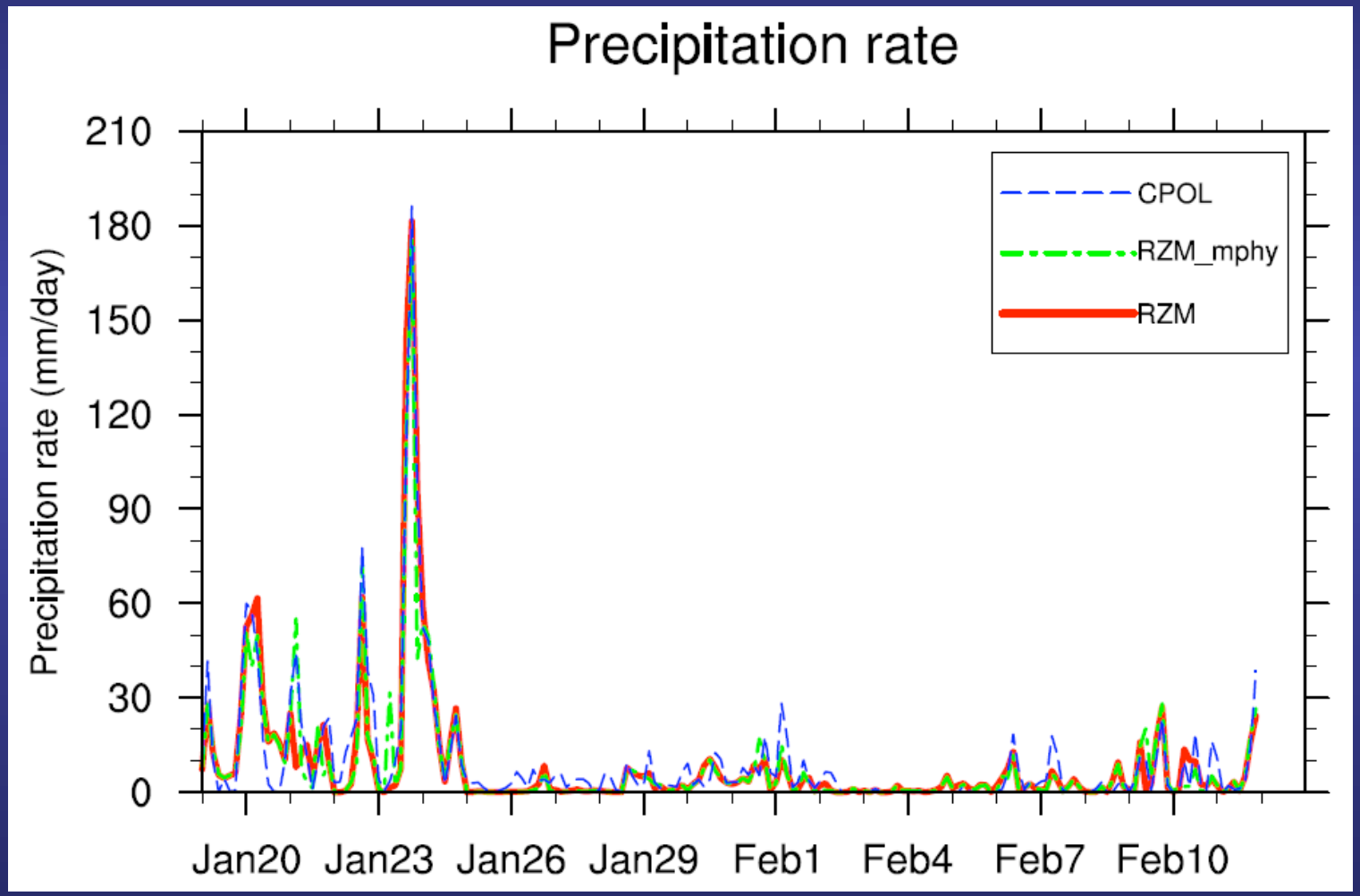
ZM_mphy



Impacts on simulation – total precipitation



Microphysics scheme with the revised ZM convection scheme



Conclusions

- Convective cloud microphysical properties using the new scheme are physically reasonable. The impact of convective detrainment on large scale environment is larger now.
- Precipitation simulation depends more closely on the closure of convection scheme than microphysics in the SCAM setting, as expected.